AIR FORCE OFFICE of SCIENTIFIC RESEARCH [AFOSR]
Manager of the Basic Research Investment for the Air Force

Research HIGHLIGHTS

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Bioelectrics – Two Worlds Combine

Dr. Christian Bickes, Post-Doctoral Research Associate at Old Dominion University in Norfolk, Va. configures equipment used in the bioelectric experiments.

What began as a quest to decontaminate water, may lead to the link that cures cancer and obesity. Such is the landmark journey embarked upon by Dr. Karl Schoenbach, an electrical engineer, and Dr. Stephen Beebe, a cell biologist. Both are funded by the Air Force Office of Scientific Research's (AFOSR) Physics and Electronics directorate.

In the early 1990s, Schoenbach, a professor at the College of Engineering and Technology at Old Dominion University in Norfolk, Va., was looking for a way to kill the bacteria that contaminated water or air through the use of pulsed power. By generating short pulses with extremely high electrical pulses, Schoenbach was able to affect the cells that caused the problems.

"Companies now use this method to decontaminate orange juice," Schoenbach said. "This method doesn't change the taste of liquids, but can kill E. coli bacteria."

Flush with that success, Schoenbach began to ponder the effects pulsed power would have on other living cells. However, he was an engineer. Enter Stephen Beebe, an Eastern Virginia Medical School pediatrics professor and a trained bio-chemist who has worked in molecular and cell biology.

No longer content with simply killing bacteria, the two focused their attention on living human cells.

"We wanted to find a way to kill bad cells, like tumors, or unwanted cells, like fat cells," Schoenbach explained. "More important, we wanted to see if we could affect their functions."

They did. Schoenbach and Beebe became the first scientists to show that cancer cells could be coaxed to die. They have also made other discoveries along the way.

"We learned that if you use pulses that are below the threshold of killing a cell, you can enhance cell function," Beebe reported. "This has applications in wound healing and expanding stem cells that could be used in gene therapy or replacement therapy."

Beebe added that the military applications of their research is infinite. He noted an experiment done on brine shrimp that demonstrated that a "little zap" temporarily stopped them from swimming, while allowing them a full recovery.

"We're thinking this could be useful with crowd control or disabling an enemy force in a non-lethal way," Beebe said.

The number of obese people could be thinned as well. In the same way cancer cells are killed, Beebe explained, so could fat cells.

"If we could kill the fat cells that carry fat, or better yet the stem cells, then we could control the number of fat cells that are available," he said.

While many have marveled at their breakthroughs, others have been pleasantly surprised by the results yielded by a team of professional opposites.

"Biologists and engineers have very different educations and use almost two different languages," Schoenbach conceded. "The process of learning to understand the other side is complicated, time consuming, and at times, very frustrating. It requires quite a lot of respect for each other.

Beebe agreed.

"We think so very differently," he began. "Things that occur to an engineer, wouldn't necessarily occur to me. But that can be a good thing. It could lead to very good ideas. It is a synergistic way to do science.

"I think this is good for science, our health, and the environment in general," Beebe added.

According to both, they would still be in the infancy of their research if not for the support of AFOSR, and specifically, AFOSR's Dr. Bob Barker.

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Ribbon cutting ceremony at the Old Dominion University Center for Bioelectrics located on the fifth floor of Norfolk's Public Health Building.

continued from page 1...

"AFOSR was the driving force behind our new facilities," Schoenbach insisted. "Their grant really changed everything. It gave us the means to do for the first time interdisciplinary research on a level such that we could move really quickly toward results.

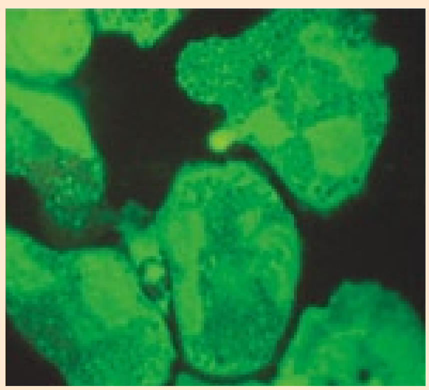
"If we wouldn't have had AFOSR and Dr. Barker, this just wouldn't exist," he added. "We probably would still be zapping our little bacteria."

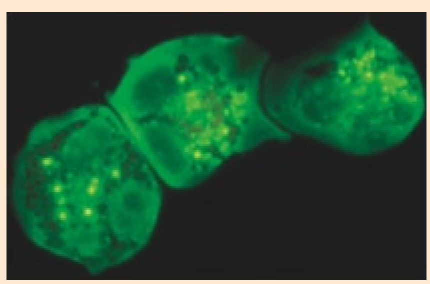
Armed with AFOSR funding, Schoenbach is confident the future will yield more breakthroughs.

"Wound healing is now a focus," he noted. "People experiencing a slow healing process, such as those with diabetes; we feel we can do a lot of good things for them.

"That is what is so exciting about basic research," Schoenbach observed. "You just don't know exactly what the outcome or breakthroughs it may bring."

Dr. Robert Barker,
AFOSR/NE 703-696-8574





Eosinophils (white blood cells) before and after the application of nanosecond pulses with electric fields of 5 million volts/meter. The after photograph (TOP PHOTO) shows inner structure opened and taken up dyes – shown as "sparklers." (BOTTOM PHOTO)

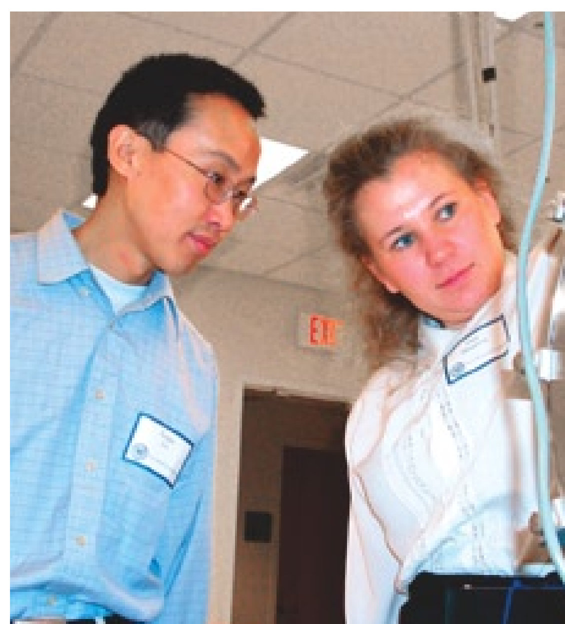
Plasma

Anyone who has had to endure the cumbersome process of decontaminating equipment or gear exposed to biological warfare agents knows it to be incredibly time consuming. However, for those on the front lines and elsewhere, a revolutionary method using plasma developed by Dr. Mounir Laroussi promises to speed up that process considerably.

Laroussi, an Old Dominion University associate professor of electrical and computer engineering, who is funded by the Air Force Office of Scientific Research (AFOSR), has been looking for a way to improve decontamination techniques for years. Conventional techniques, he said, have relied on extreme heat or chemicals to deal with biohazards. Such methods, Laroussi noted, were not suitable for many situations.

"You can apply plasma wherever you are, whenever you may need it," he said. "The beauty is that it is very efficient. You can decontaminate surfaces in a few seconds to minutes."

Plasma, according to literature from the Coalition of Plasma Science (CPS), is formed when enough energy is added to a gas to free electrons from a significant number of atoms or molecules. The process, known as ionization, creates a mixture of positively



Drs. Xinpei Lu and Olga Minayeva, Post-Doctoral Research Associates in t
department of Old Dominion University in Norfolk, Va. work to further

charged particles, negatively charged particles, and various uncharged particles. Among these particles can be high concentrations of so called "free radicals." These free radicals, states the CPS source, can quickly overwhelm the natural defenses of living organisms, leading to their destruction. It is why, Laroussi explained, plasma is a very efficient decontamination agent.

Plasma also promises to serve those in the military and civilian medical communities, he said.

"Plasma will help in the decontamination and sterilization of reusable medical tools that are heat sensitive," Laroussi stated. "Most of the methods use very hot, moist air. Another method of sterilization used in hospitals is to use toxic gases, such as ethylene oxide. That requires a lot of time; about two hours of treatment and 24 hours to allow for the gases to dissipate and all the residues. This is very time consuming and not very friendly to people or the environment."

With plasma, Laroussi continued, medical professionals without the luxury of excess sterilized equipment working in makeshift hospitals near the battlefield can reuse their tools over and over. "The tools can be sterilized in just a few minutes," he said.

he Electrical and Computer Engineering
Cold Plasma research.

Decontamination is not the only advantage of plasma use. Researchers foresee aerodynamic applications as well.

"If you have an airplane or jet with this kind of plasma," he observed, "at some critical point you can reduce the drag. That means saving fuel."

Scientists also discovered that high concentrations of bacteria can be killed after exposure to plasma in as little as 10 seconds. Tests have demonstrated, according to a CPS document, that microorganisms similar to anthrax and bacteria, such as Escherechia coli (commonly referred to as E. coli), can be neutralized by plasma. Its use also may prove effective in destroying prion, the protein linked to "Mad Cow disease."

"We start with one million Bacillus spores and can reduce them to a few hundred in a matter of seconds," Laroussi said. "It's very potent stuff."

While the possibilities for plasma use seem limitless, Laroussi is certain they wouldn't be so if not for the support from AFOSR.

"At the time that AFOSR began funding this plasma research (mid-1990s), there practically wasn't anyone doing this type of research," Laroussi explained. "AFOSR's Dr. Bob Barker (program manager for AFOSR's Physics and Electronics directorate) was a visionary in foreseeing the value of it and the potential use for the Air Force and military.

"When we started this research there were few people doing it," he added. "Now there are groups everywhere all around the world – Europe, Japan, United States, Russia...everywhere. This research has become a mainstream thing."

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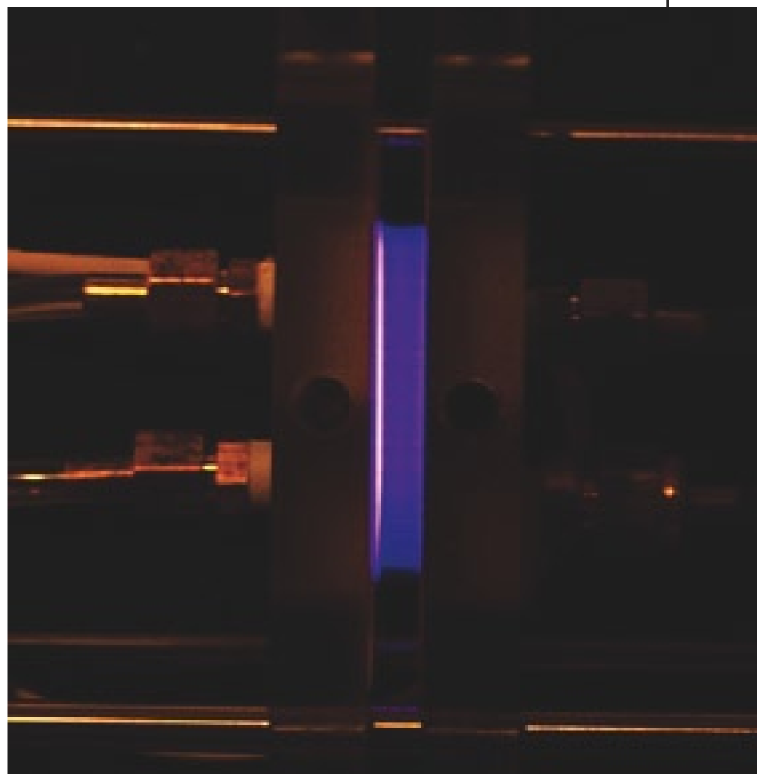
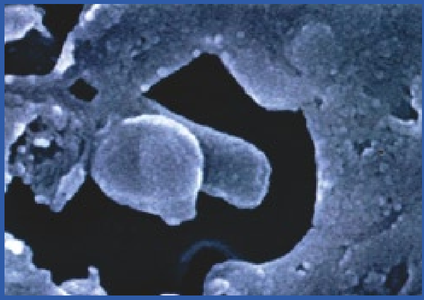


ABOVE: Air plasma source (Laroussi et al.)

SEM micrograph of E.coli in the control sample.



SEM micrograph of E.coli treated by plasma.

Osher Wins Pioneer Prize

Dr. Stanley Osher, an Air Force Office of Scientific Research-funded scientist, recently received the 2003 Pioneer Prize from the International Congress on Industrial and Applied Mathematics for his outstanding contributions to applied mathematics and computational sciences.

As the director of applied mathematics at UCLA, Professor Osher was recognized for his pioneering work on shock-capturing schemes, PDE-based image processing, and the level-set method.

Dr. Stanley Osher

Professor Osher's work on shock-capturing schemes for conservation laws has been extremely influential in computational fluid dynamics (CFD). In the late 1970s and early 1980s he developed, with various collaborators, monotone and total-variation-decreasing (TVD) schemes. They quickly became very popular. Later, with collaborators, he introduced essentially-non-oscillatory (ENO) schemes that have found widespread use in compressible CFD.

Osher's work with L. Rudin on total-variation-based image restoration was among the first applications of PDE methods to image processing. This work has been very influential, stimulating mathematical research on PDE-based image analysis, and leading to the development of related methods for various inverse problems.

His work on level set methods represents a fresh, very powerful approach to the numerical solution of evolutionary free-boundary problems. In the late 80s, with J. Sethian, Osher addressed the propagation of codimension-one fronts with curvature dependent speed. Since then, with various collaborators, he has addressed a wide variety of related problems, developing techniques for handling nonlocal velocity laws, triple junctions, and higher-codimension sets. He has, moreover, demonstrated the value of these techniques by applying them to problems from materials science, geometry, and fluid dynamics.

Dr. Arje Nachman, a Program Manager with the AFOSR's Mathematics and Space Sciences directorate, said Dr. Osher's research could benefit the U.S. military. "The goal is to develop a high quality simulation tool that would help us to design a multi-use warhead that can explode in a variety of patterns, such as anti-armor and anti-personnel. Tracking the shock waves within the solid explosive which are initiated by microdetonators is a key to predicting the resulting pattern and such shock fronts can only be tracked by the level set method," he said.

Research Highlights

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